and the observer may both be considered as located at the center of the celestial sphere C, because, owing to the indefinitely great radius of the sphere, rays from sun to observer and from sun to crystal may be considered as identical; the background extension of a refracted ray will then pierce the sphere at the point where the observer sees the resulting virtual image.

The rational horizon EE will then be the intersection of the plane of the top face with the celestial sphere; let $ZSMC$ be the plane of the vertical circle through the sun, $ZAPC$ a principal plane of the crystal indefinitely extended, and $ZS'C$ the plane of the vertical circle through the image; if SC be the incident ray making the angle ACS (measured by the arc h) with the given principal plane, then the refracted ray $S'C$ must also make the angle h with the principal plane. As the angle PCM varies from 0° to 90°, h varies from 0° to the angle ZCS (zenith distance of the sun); and from the laws of refraction and the known altitude of the sun the position of S' can be computed, by means of the chain of spherical triangles, for any assumed value of h.

THE GRAND JUNCTION HALO OF MARCH 3, 1906.

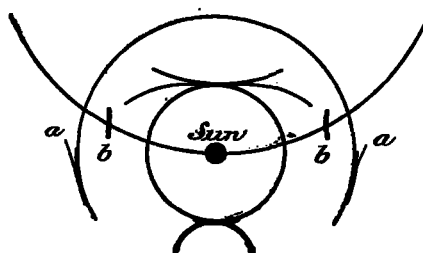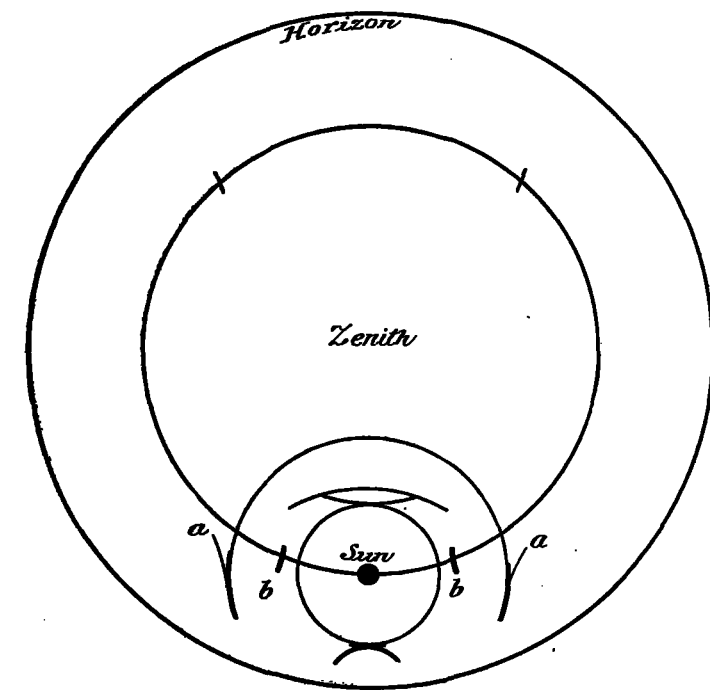In the MONTHLY WEATHER REVIEW for March, 1906 (vol. 34, pp. 123–124), there is recorded an observation of

FIG. 1.—Halo observed at Grand Junction, Colo., March 3, 1906, by G. H. Ferguson.

a halo observed at Grand Junction, Colo., on March 3, 1906. The description given there is very meager, but

the figures, here reproduced as figure 1, leave no doubt but that the upper and lower Parry arcs were present "The second drawing shows a slight change, there being a difference of about one hour between the two." The times of observation are not stated, and it is clear that the horizon is shown too low in the first figure in proportion to the scale of the halo, because the Parry arc, being produced by the same crystals as cause the upper tangent arc, merges indistinguishably with the latter at a comparatively low solar altitude. In the second figure, the Parry arc has disappeared, and an arc has become visible which is probably the sunward part of what Hastings calls the "lower oblique arcs passing through the anthelion."—*Edgar W. Woolard.*

OUTLINE SHOWING THE FORMATION OF THE ELEMENTS OF A HALO COMPLEX.

By EDGAR W. WOOLARD.

[Weather Bureau, Washington, D. C., July, 1920.]

I.—REFRACTION PHENOMENA.

Orientation of refracting edges.	Phenomena produced.	
	60° angle.	90° angle.
Vertical:		
Minimum deviation	22° parhelia	46° parhelia. Tails to parhelia. Supralateral and upper bitangent arcs. Infralateral and lower bitangent arcs.
Other deviations	Tails to parhelia	
Horizontal:		
Minimum deviation	Upper and lower tangent arcs to 22° halo.	
Other deviations	Upper and lower Parry arcs.	Circumzenithal arc. Circumhorizontal arc.
Inclined:		
Normal to planes through eye and sun—		
Minimum minimorum	22° halo	46° halo (?).
Other deviations	Glare outside halo	Glare outside halo.
In vertical planes through sun.	Arcs of Lowitz [1]	

II.—REFLECTION PHENOMENA.

Orientation of reflecting faces.	Phenomena produced.	
	Partial external or internal reflection.	Total internal reflection.
Vertical	Parhelic circle	Parhelic circle.
Horizontal	Sun-pillar	
Inclined	Oblique arcs of the anthelion (?).	
Multiple reflections	Anthelion and oblique arcs of the anthelion (?).	
Reentrant angles	120° parhelia (?)	

III.—MISCELLANEOUS.

Processes.	Phenomena.
Combinations of refraction and reflection	"Upper and lower oblique arcs passing through the anthelion." 120° parhelia (?). Paranthelic arc (?). Kerns arc (?). 90° halo (halo of Hevelius). 136° halo (Bouguer halo, false white rainbow).
Miscellaneous	90° parhelia. Vertical parhelia. Mock suns. Extraordinary halos. Secondary halos.

[1] See, however, S. Fujiwhara, On the Theory of Lowitz's Arc, Proc. Tokyo Mathematico—Physical Soc., ser. 2, vol. ix, pp. 502–515, 1918.